A critical appraisal of the European Commission´s policy towards regulating next generation communications networks

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Abstract

Fiber-deployment of telecommunications networks is currently a great challenge for sector-specific regulators, national governments, as well as for investing operators. One of the most controversial regulatory issues in Europe (and elsewhere) is whether the emerging next generation access (NGA) infrastructure should be subjected to cost-based access regulation or whether at least a temporary removal of ex ante obligations (“regulatory holidays”) should be granted.

In answering this question we examine the current and foreseeable EU regulatory framework and show that it does not provide positive incentives for NGA deployment and increasing penetration rates. On the basis of an international comparison with the most recent data on NGA deployment and penetration, it appears, in turn, that deregulatory and/or state aid driven approaches targeted at the demand (subscribers) and supply side (coverage) are more promising.

1 Introduction

In recent years, fiber-deployment of telecommunications access networks ("Next Generation Access" - NGA) has become a major issue for sector-specific regulators, governments, as well as for investing firms. Operators of traditional ("first generation" copper-based) telecommunications networks have to speed up their networks to fulfill needs for growing demand for bandwidth, arising from new/interactive multimedia services like streamed video on demand, High Definition Television, 3-D applications, cloud computing, Web 2.0 services, as well as for the increasing backhaul demand of mobile operators who are confronted with an explosion of mobile broadband services. The renewal of existing networks and their (partial) replacement by fiber-optic infrastructure require high investment volumes.[1] The future central importance of ultra-high-speed broadband infrastructure as a key socio-economic factor in any information society is well recognized.[2] However, investment in ("second or next generation") fiber-based network infrastructure varies significantly in international comparison.

Whereas leading Asian countries take a state aid driven approach, the United States (US) adopted a deregulatory and primarily market-driven strategy. The European Union (EU), in contrast, relies on competitive market forces subject to a set of strict sector-specific regulations (Huigen & Cave, 2008). One of the most controversial regulatory issues in Europe (and elsewhere) is whether the emerging NGA infrastructure should be subjected to cost-based access regulation or whether at least a temporary removal of ex ante obligations ("regulatory holidays") should be granted. A further point of discussion is the role of national governments in promoting the necessary funding of business models.[3]

Our paper addresses the following research question: Can different patterns in NGA deployment and penetration be systematically related to different sector-specific and governmental policies? In view of the theoretical contributions on the trade-off between static and dynamic efficiency, as well as the vast majority of the empirical literature, we argue first that the current EU regulatory framework of a rather strict regime of cost-based access pricing is likely to lower both, NGA infrastructure investment in terms of coverage ("homes passed") and as a consequence also penetration levels in terms of subscriptions ("homes connected"). Second, given the extremely high investment requirements and risks of NGA roll-outs, it is also unlikely that private investment activities will be induced by competition alone on a nation-wide scale. For non-profitable ("white") areas, in particular, public funding will be the only driver of NGA deployment (supply side subsidies) as well as of penetration

[1] Total investments for a nationwide NGA deployment add up to billions of euros (wik consult, 2008).

[2] For evidence on the positive impact of broadband deployment on employment, productivity and economic growth, see for instance Röller and Waverman (2001), Crandall et al. (2007), Garbacz and Thompson (2007), Koutroumpis (2009) or Czernich et al. (2011).

[3] The subject area is even more extensive, as a systematic fiber-based roll-out is no longer just a matter of traditional telecommunications operators. Rather, public utilities from other network industries such as energy and transport might have opportunities and incentives to expand their product portfolio.

(demand stimuli). It is important to note here that our purpose is not to identify the determinants of NGA deployment and penetration but to examine the differential impact of alternative NGA policy strategies.

In order to examine our research question we employ a twofold research methodology: First, we compare the EU regulatory framework for electronic communications with representative regulatory policies, as well as NGA deployment and penetration patterns in non-EU27 countries. Second, we run non-linear diffusion regressions in order to identify the respective diffusion stages. For our empirical analysis we employ the most recent data on NGA deployment and penetration in leading NGA countries. NGA roll-out and subscriptions are measured narrowly in terms of fiber-to-the-home/fiber-to-the-building (FTTH/B) lines for the time range from 2001 to 2011 for biennial data.

The remainder of the paper is organized as follows: We review the telecommunications-related literature in section 2. Section 3 describes our basic hypotheses on investment and regulation as well as public subsidies. Section 4 outlines the data and definitions underlying our empirical examination. Section 5 contains the empirical analysis and interprets the main results. Section 6 summarizes and concludes.

2 Literature review

Early empirical studies related to the impact of regulation on investment concentrate mostly on US experience with wholesale access regulation, suggesting that regulated cost-based access charges would reduce investment incentives for incumbents and for competitive bypass (e.g. Chang et al., 2003; Ingraham & Sidak, 2003; Crandall et al., 2004). More recent work exhibits similar results: Grajek and Röller (2011) investigate the relationship between regulation and total investment in the telecommunications industry. Investment is quantified therein rather broadly by the tangible fixed assets of telecommunications operators and, thus, does not explicitly refer to broadband or NGA deployment. Wallsten and Hausladen (2009) are the first to estimate the effects of broadband access regulation on NGA investment within the EU. However, they use highly fragmentary data from the EU's Communications Committee for the years from 2002 to 2007, which only covers the NGA roll-out at the very early stage. They find that countries where unbundling is more effective experience lower fiber penetration. Briglauer et al. (2012) investigate the determinants of NGA investment with a direct measure of real and most recent NGA investment. They find that stricter previous broadband access regulation has a negative impact on NGA deployment, while competitive pressure from broadband and mobile affects NGA deployment in an inverted U-shaped manner. Cambini and Jiang (2009) survey the empirical literature and find that the majority of the studies conclude that cost-based access regulation discourages both incumbents and alternative operators from investing in fixed networks. Finally, Nitsche and Wiethaus (2011) model the effects of different regulatory regimes on NGA investment and welfare, and find that regimes of fully distributed costs or regulatory holidays are most positive for investment. Their simulations further show that a risk-sharing approach is best from a welfare point of view.

Regarding the literature on the impact of regulation on penetration, there are quite a few contributions related to broadband markets, but actually no NGA-related studies: Early US-related work (Burnstein & Aron, 2003) found that infrastructure-based competition has a positive impact on broadband diffusion in the longer term, whereas service-based competition has a positive impact only in the initial market phase. Wallsten (2005) found that only a few regulatory policies had any significant impact on broadband penetration. Non-US based work that measures the impact of access regulation on broadband penetration mainly refers to OECD country-level data: Wallsten (2006) finds a negative effect of subloop unbundling whereas full local loop unbundling has no significant effect for the years 1999 to 2003. Bouckaert et al. (2010) examine the determinants of broadband penetration for the years 2003 to 2008. They find that infrastructure-based ("inter-platform") competition has a positive impact on broadband penetration, whereas service-based ("intra-platform") competition is an impediment to penetration. Lee et al. (2011) analyze determinants of broadband diffusion for the years from 2000 to 2008. With respect to their regulatory policy variable, Lee et al. find a positive and significant effect of unbundling obligations on the speed of diffusion. The authors admit, however, that unbundling might have a negative impact on long-term investment and the broadband saturation level. Also, OECD countries are highly heterogeneous as regards regulatory unbundling regimes and other market conditions. Finally, some contributions refer to data from European countries: Distaso et al. (2006) analyze EU-related data and find that inter-platform competition has a more important role for penetration than service-based competition, especially in the longer term. Höffler (2007) examines data for Western Europe for the years from 2000 to 2004. He concludes that broadband deployment was predominantly triggered by infrastructure-based competition, with service-based competition relying on regulated DSL services playing a secondary role. But infrastructure duplication might lead to welfare losses.

Summarizing, the general trade-off between static and dynamic efficiency is well recognized in the literature. The majority of the empirical literature suggests that strict cost-based broadband access regulation negatively affects both, investment and penetration.

3 Hypotheses

This section sets out our hypotheses, which are first derived from an analysis of the impact of the EU regulatory framework on investment in broadband and NGA infrastructure. Section 3.2 then outlines the specific risks and natural monopoly characteristics of NGA networks and describes the basic economic rationales for subsidizing NGA deployment.

3.1 Regulation and NGA deployment

The recommendation of the European Commission (EC) on regulated access to next generation access networks[4] in conjunction with its recent consultation on the future regulation of NGA infrastructure[5] forms the starting point of our discussion in section 3.1.1. Following this, section 3.1.2 contains a critical assessment and outlines our hypotheses in this case.

3.1.1 The EU regulatory approach

In the EU, regulated wholesale broadband access prices are usually based on diverse cost-oriented standards which have been established since the very beginning of the liberalization process in communications markets in 1997/1998. Tight cost-based regulation of existing broadband access products most likely has already created corresponding expectations about the future regulation of NGA access products. Indeed, some European countries started to introduce such regulations on wholesale broadband access over NGA (such as Belgium, Denmark, Italy, Netherlands or Spain), on fiber unbundling (Finland and Netherlands) or on NGA-specific capital costs (Netherlands) in 2010 (Cullen International, 2011, Tables 4, 9, 10). In its recommendation the EC strictly believes that it can enhance NGA roll-out by means of a consistent cost-based access pricing approach over time and across all member states (European Commission, 2010a, recitals 3, 6, art. 6).[6] The EC´s recommendation in conjunction with its consultation document on costing methodologies (p. 9) expresses clearly that there will be a need for ex ante regulation of emerging NGA infrastructure (European Commission, 2010a, recitals 18, 32, art. 14, 20, 25, 30, 35). In the EC's view, superiority of cost-orientated access regulation has been proven to guarantee to (i) stimulate effective competition via service-based downstream competition, (ii) ultimately generate higher consumer welfare and (iii) bring about appropriate investment signals (p. 2 of the consultation document).

The EU regulatory framework tried to resolve the trade-offs of dynamic and static efficiency with reference to the so-called "ladder of investment" approach (Cave, 2003; Cave & Vogelsang; 2003; Cave 2006),[7] which is also seen as a guiding principle for NGA networks (European Commission, 2010a, recital 3). On p. 4, the consultation document states that access pricing should be designed to "safeguard the investment ladder principle" and to guarantee consistent regulation across wholesale

[4] European Commission (2010a), hereinafter referred to as the "(NGA) recommendation". Although a recommendation is not legally binding on member states, it has to be considered to "the utmost account" in regulatory decision-making processes. Moreover, the "Telecoms Package" amended in 2009 provided the EC with additional influence and power vis-a-vis national regulators.

[5] Consultation document on "costing methodologies for key wholesale access prices in electronic communications" (hereinafter referred to as the "(NGA) consultation document") and results are available at: http://ec.europa.eu/information_society/policy/ecomm/library/public_consult/cost_accounting/index_en.htm.

[6] See also Ruhle and Lundborg (2009), who examined the draft version of the NGA recommendation and showed that the EC is determined to continue and evolutionary develop the regulatory framework.

[7] The initial ideas developed in Cave and Vogelsang (2003) have been incorporated into a report for the EC (Cave, 2003) and were then elaborated in more detail in Cave (2006).

access products. According to this hypothesis, regulators should initially encourage alternative operators to engage progressively in backward integration after having entered the market as simple resellers on the basis of dynamically adjusted cost-oriented charges. In order to climb up the ladder, service-based competition is seen as an indispensable prerequisite for infrastructure-based competition. With respect to wholesale broadband access, resale and bit-stream should have facilitated quick and easy market entry and established a customer base and reputation during the first stage of liberalization. Subsequently, entrants are supposed to migrate towards unbundling activities, reap the benefits of product differentiation and ultimately move towards self-deployed infrastructure investment. The latter would constitute the highest rung of the ladder, where alternative operators were fully integrated and fully bypass the incumbent´s infrastructure and did not depend any longer on ex ante access obligations. Thus, at the bottom of this principle, there is the vision of a continuous transition path from monopoly towards self-sustaining competition, with asymmetric ex ante regulation being only a necessary intermediate phase. The dynamics of the transition can be influenced by the regulator via the availability of access instruments and the level of access charges during the liberalization process.[8] The ladder of investment hypothesis therefore rests on two propositions (Cave, 2010, p. 84): Infrastructure-based competition is preferred when it is reasonably achievable and the regulator can implement suitable regulatory instruments to achieve that goal.

In order to foster the switch from the “old” copper ladder towards the “new” NGA ladder, the consultation document (p. 10) suggests fostering NGA investment by gradually eliminating rents from the old (legacy) network infrastructure and ultimately threatens with short-run incremental costs to be imposed on the incumbent network if migration to the new network infrastructure is deemed to be insufficient in view of the targets of the EC´s Digital Agenda (European Commission, 2010b, p. 19). Obviously, such a policy aims to eliminate the so-called replacement effect (Arrow, 1962). The replacement effect occurs if NGA investments were to “cannibalize” economic profits from preceding broadband (xDSL) services provided via legacy infrastructure, which would ceteris paribus reduce profitability and the incentive to invest in new infrastructure.

3.1.2 Assessment of the EU regulatory approach

In its recommendation the EC stipulates that cost-based regulation of NGA wholesale access products will be required in view of a time-consistent access regulation approach proven over many years.

[8] The regulatory tools could also entail complete withdrawing of some or all of the wholesale access obligations at a predetermined date (Cave, 2006). Such “sunset clauses” provide ultimate incentives to build one’s own infrastructure but might be subject to the regulatory commitment problem. Indeed, lack of credibility with sunset clauses was experienced in the Netherlands and in Canada (Borreau et al., 2010, p. 690-691).

Alternative pricing regimes targeted at increasing pricing flexibility[9] are not mentioned in the consultation document, and deregulation in terms of regulatory holidays has been clearly dismissed, as it has already been announced in previous publications (e.g. European Commission, 2007). According to simulation calculations in Nitsche and Wiethaus (2011), a regime of fully distributed costs or regulatory holidays would have the most positive effects on NGA investment, whereas the current cost standard, based on long-run incremental costs, turns out to be inferior. Indeed, for the following reasons established strict cost-based access regulation can be expected to reduce investment activities of infrastructure operators: (i) imposing cost-oriented prices for bottleneck inputs will typically reduce profits or preclude excess profits of the regulated firm, which results in an asymmetric distribution of expected profits and, therefore, in a lower net present value of investment projects (Valetti, 2003). Furthermore, regulated infrastructure operators criticize that (ii) access regulation typically ignores opportunity costs of real options (Guthrie, 2006) and that (iii) risks were distributed asymmetrically as service-based operators benefit at the same time from a risk-free option due to mandatory access obligations imposed on the incumbent operator (Pindyck, 2007). Moreover, (iv) within the EU regulatory framework risks were measured within the scope of the firm´s capital costs related to legacy networks and deemed to be not much different from the overall company risk (Cullen International, 2010, Tables 10, 15-16). The EC acknowledges the considerable risks of the NGA roll-out and recommends that higher risk should be solely reflected in the cost of capital of the regulated operator (European Commission, 2010a, recitals 18, 23, art. 25). However, this approach does not provide sufficient investment signals in case of low retail demand, since in this case even a rather high risk premium at the wholesale level cannot compensate the operator for the financial losses.[10] Accordingly, other modes to incorporate NGA-specific risks might be more favourable. Nitsche and Wiethaus (2011) showed that a risk sharing approach is best from a welfare point of view.

The requirement of a consistent approach for regulating NGA infrastructure across member states can be questioned first in view of country-specific differences such as different deployment costs: building law requirements, rights of way, regulations on and availability of ducts or the number of greenfield constructions, demographic and topographical differences (in particular, population density and housing structure in terms of the proportion of multiple dwelling units) or differences in labor costs (in particular, civil engineering). Similarly there might be systematic differences as regards demand for NGA services. One might think of country specifics concerning the affinity towards ICT and the diffusion of consumer electronics, cultural differences, the proportion of “digital natives” or household

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[9] Regulators might for instance also consider retail-minus, diverse risk-sharing approaches, combinatorial regulatory approaches, co-operation models or more light-handed cost-oriented approaches as relevant alternatives.

[10] Granting NGA-specific risk premia might also be subject to a regulatory commitment problem, since regulators have an incentive to set access prices close to marginal cost after the investment is made (Brito et al., 2011, p. 821). Unless regulators can commit credibly to announced policies in advance, investment incentives will be lower.

income as proxies for the local appetite for high-bandwidth services. Furthermore, consistency per se is neither necessary nor sufficient for economic efficiency or maximizing welfare. Also, it remains to be shown convincingly that differences in NGA wholesale access prices would induce negative cross-border effects and thus lower welfare among member states (compared to the scenario where wholesale access prices are set according to country-specific costs).

Overall, the above arguments suggest that the requirement to impose a consistent cost-oriented access pricing methodology will be detrimental to investment in new infrastructure where no legacy monopoly-like structure exists.[11] With respect to well-established first generation infrastructure, the EC intends to neutralize the replacement effect which, however, would not only bring about a massive destruction of assets of copper, which still has – although largely depreciated – a positive economic value, especially, in light of the potential of "second life" technologies (VDSL/FTTC, Vectoring VDSL with bandwidth up to 100 Mbit/s or above).[12] Moreover, such a policy ignores other crucial effects at the wholesale and retail levels since (i) lower access charges for copper will directly reduce wholesale revenues. In addition, lowering access charges for copper infrastructure might also enforce expectations of strict and heavy-handed regulation of future NGA wholesale products, which mitigates or at least postpones incentives to invest in NGA infrastructure. Furthermore, (ii) lower access charges for copper will also be translated into lower retail prices given the competitiveness of broadband markets, which, in turn, will have an effect on the prices of substitute NGA products. Lowering copper prices below long-run average incremental cost levels and eventually towards short-run incremental costs would further increase the price gap between current copper services and future NGA products, which will ceteris paribus reduce consumer incentives to switch even more. This holds especially in case consumers do not show sufficient demand for ultra-fast broadband applications or are largely satisfied with existing broadband services. Whereas (i) might be referred to as a "wholesale revenue eliminating effect", (ii) stands for an "ARPU eliminating migration effect" at the retail level.

Finally, the ladder of investment approach requires regulators to micromanage the industry in general, which is immediately related to the standard problems of asymmetric information. Empirically, there has been hardly any convincing support for the successful implementation of the ladder of investment concept so far.[13] Especially, due to the natural monopoly characteristics of the last mile, reaching the goal of infrastructure-based competition (last rung of the ladder) was largely forestalled. The dynamic concept of transition from service-based towards infrastructure-based competition becomes even more

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11 Traditional incumbent operators typically own some strategic assets and may benefit from certain cost advantages in upgrading networks. However, migration towards NGA infrastructure will basically constitute "symmetric markets" (Bourreau et al., 2010, p. 693), which questions the conception of asymmetric ex ante regulation, especially, if the new infrastructure is not yet in place.

12 Although these technologies are not yet completely developed they can be expected to achieve market maturity soon (see RTR, 2011, p. 5).

13 See Bouckaert et al. (2010), as well as Bourreau et al. (2010, p. 689-690), who review the empirical evidence on the ladder of investment.

unlikely against the backdrop of NGA deployment, as economic replicability will be even lower in view of NGA-network topologies.[14] As a consequence, the stylised ladder of investment for NGA wholesale access products tends to be reduced to a very few rungs for service-based operators. Indeed, recent regulatory decisions[15] suggest that service-based providers rather have to take a step back down on the NGA ladder (OECD, 2011, p. 23-24).

Summarizing, the EU framework does not provide sufficient incentives for investment in new infrastructure. The direct impact of strict access regulation on infrastructure-based operators is likely to be negative and we also do not expect a positive indirect impact of access regulation on NGA deployment via service-based competition as idealised by the ladder of investment hypothesis.

3.2 Economic rationales for subsidizing NGA deployment

NGA development is not only associated with substantial investment, but also with high uncertainty and high risks for potential investors. Compared to duct costs and fibreglass, digging costs are of major importance (60-80% of total costs) and are largely and literally sunk in nature (ERG, 2007, p. 16-17). Whereas incumbent operators owning legacy networks are confronted with a largely depreciated infrastructure, the costs of second generation networks are not sunk before the investment decision is actually made. However, foreseen sunk costs might delay any future investment or make them even unprofitable (see Cave & Martin 2010, p. 1). Next to the risks associated with the intrinsic sunk cost nature of NGA investment, investors also have to consider the following risks: Long amortization periods (20-25 years) of network infrastructure, the technical risk of the new technology and the economic risk of unknown demand for new services against the backdrop of consistently decreasing prices. Finally, NGA investors might be subject to regulatory risks, since the actual design of ex ante obligations to be levied upon NGA network operators is still to be defined or implemented in many countries and might then be also subject to the regulatory commitment problem.[16]

Given the high investment requirements and the specific risks of NGA projects, it is unlikely that private investment will be induced by competition or sector-specific regulation on a nation-wide scale. Public investment is usually justified by positive externalities of communications networks. In case of NGA, increasing efficiency and decreasing costs in other business sectors would represent such

[14] According to the extensive study of wik consult (2008), a competitive duplication of fixed access network infrastructure is at most economically feasible in very densely populated areas. But still, even in such a case the second operator needs to have a high market share.

[15] The well-known wholesale fiber-access product of the British regulator (“Virtual Unbundled Local Access”, VULA) is, with respect to the degree of product differentiation and technical control, much closer to previous bit-stream access products than to access based on local loop unbundling.

[16] A more general discussion of NGA-specific risks can be found in ERG (2009).

positive effects.[17] Also, governments and municipalities seem to become more and more inclined to see high-speed broadband infrastructure as a necessary competitive tool to attract international business and to increase the competitiveness of their countries and regions (Falch & Henten, 2010, p. 2). Finally, due to the economies of density, funding will be particularly important for white areas where NGA provision is most difficult. For such – mainly rural – areas, funding is also to be expected, because otherwise a politically unacceptable gap to urban areas ("digital divide") would increase. Overall, the economic rationale for subsidizing NGA roll-outs rests upon market failure, macroeconomic reasoning and equity motives and, thus, intervention is largely covered by mainstream economics (Gomez-Barroso & Feijob, 2010, p. 488-490).

Summarizing, it appears that public funding targeted at the supply and demand side will ceteris paribus have a positive impact on NGA deployment and penetration. Most notably, public subsidies seem to be essential for covering white areas.

4 Data and definitions

As our main source we use the database of FTTH Council Europe, which includes bi-annual numbers of deployed NGA lines ("homes passed") as well as for NGA subscribers ("homes connected") for European countries for the period from 2004 to 2011.[18] For non-European countries we use data from the FTTH Council Europe`s sister organizations for the period from 2001 to 2011. In addition, we had to use data from the "progress reports" of the EU[19] as well as a few other individual sources to complete the series. Finally, we use the "International Telecommunications Union (ITU)" database for the number of households (*HH*) per country in order to normalise all the NGA figures of interest.[20]

NGA deployment in terms of real investment in physical units is represented by the number of homes passed by FTTH/B, *FTTHB_cov*, per household. Homes passed refer to the number of households that have access via FTTH/B but need not have a corresponding retail contract. Homes passed may or may not be connected to the network and therefore differ from the actual number of homes connected, which is the number of households exhibiting a sufficient willingness to pay and actively using at least one of the FTTH/B services on this connection under a commercial contract. Again, the number of homes connected by FTTH/B, *FTTHB_pen*, is normalised to households. FTTH/B represents fibre lines/connections in the narrower sense, where fibre infrastructure terminates inside or no more than two meters away from the consumers' building, either the basement, the house or the apartment. In turn, FTTx stands for NGA infrastructure in its broad sense including FTTH/B, Fibre to the curb

[17] A recent OECD study (OECD 2009) argues that even slight spill-over effects are sufficient for justifying subsidies for NGA deployment on economic grounds. Especially, sectors such as health care, electrical power and transport would benefit from NGA deployment.

[18] Source: http://www.ftthcouncil.eu/resources?category_id=6.

[19] Source: http://ec.europa.eu/information_society/policy/ecomm/library/index_en.htm.

[20] Source: http://www.itu.int/ITU-D/ict/publications/world/world.html.

(FTTC), VDSL, VDSL2 and Fibre to the last amplifier (cable and FTTx/LAN).[21] Consistent data series for European and non-European countries are only available for FTTH/B. Yet focusing on a narrow NGA definition also makes good sense as it helps to highlight the role of regulation and state aid policies, as in the case of FTTH/B investment requirements, and risks will be highest.[22]

Summarizing, all sources and variable definitions as well as descriptive statistics are listed below in Table 1 and Table 2, respectively.

Table 1: Variable definitions and sources

Variable	Description	Source
FTTHB *FTTHB_pen*[a]	Number of households connected to FTTH/B lines Number of households connected to FTTH/B lines normalized to total households	Main source: FTTH Council Europe, FTTH Council North America, FTTH Council Asia Pacific Complementary sources: EU Progress report for Latvia, Lithuania, Slovenia, Slovakia (2004-2006) ITU for South Korea (2001-2007) Ministry of International Affairs and Communications http://www.soumu.go.jp/english/) for Japan (2001-2005) RVA LLC (2010) for US (2001-2007)
FTTHB_cov	Number of households passed by FTTH/B lines normalized to total households	FTTH Council Europe, FTTH Council North America, RVALLC (2010), FTTH Council Asia Pacific
HH	Number of households per country	ITU World Telecommunication/ICT Indicators Database
date	The number of elapsed half years since 1 January 1960	Stata´s internal numeric date

[a] 12.5% and 20% of the raw data had to be created by using our own estimations and linear interpolation for European and non-European countries, respectively.

Table 2: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
FTTHB	608	710320.9	2521031	0	2.22e+07

[21] Full definitions of terms are available at: http://s.ftthcouncil.org/files/FTTH-Definitions-Revision_January_-2009_0.pdf.

[22] Because the length of fibre lines is longer compared to other FTTx technologies and thus services a smaller customer base in the last section, the average cost and the required investment of FTTH/B are disproportionately higher (wik consult, 2008).

FTTHB_pen	608	.0446772	.0942733	0	.5850197
FTTHB_cov[a]	43	.2926	.308268	.05	1
HH	638	1.36e+07	2.35e+07	116030	1.22e+08
date	638	95.37774	4.864888	82	103

[a] Data refer to cross-sectional observations as of June 2011.

5 Empirical analysis

In section 5.1, we contrast NGA deployment and penetration patterns in EU27 member states with developments in the US, leading Asian and other non-EU27 countries.[23] As European countries are quite heterogeneous with respect to their competitive structures, we also have to take a closer look at the conditions within these states. This allows us to identify European and non-European groups (“clusters”) of countries with distinctively different competitive conditions and policies as regards sector-specific regulation and state aid. In section 5.2, we contrast the progress in NGA roll-out and adoption with the most comprehensive public funding initiatives in the world. Finally, in section 5.3 we run diffusion regressions to analyze the diffusion process in each of these countries (clusters).

5.1 Global FTTH/B ranking and sector-specific regulation

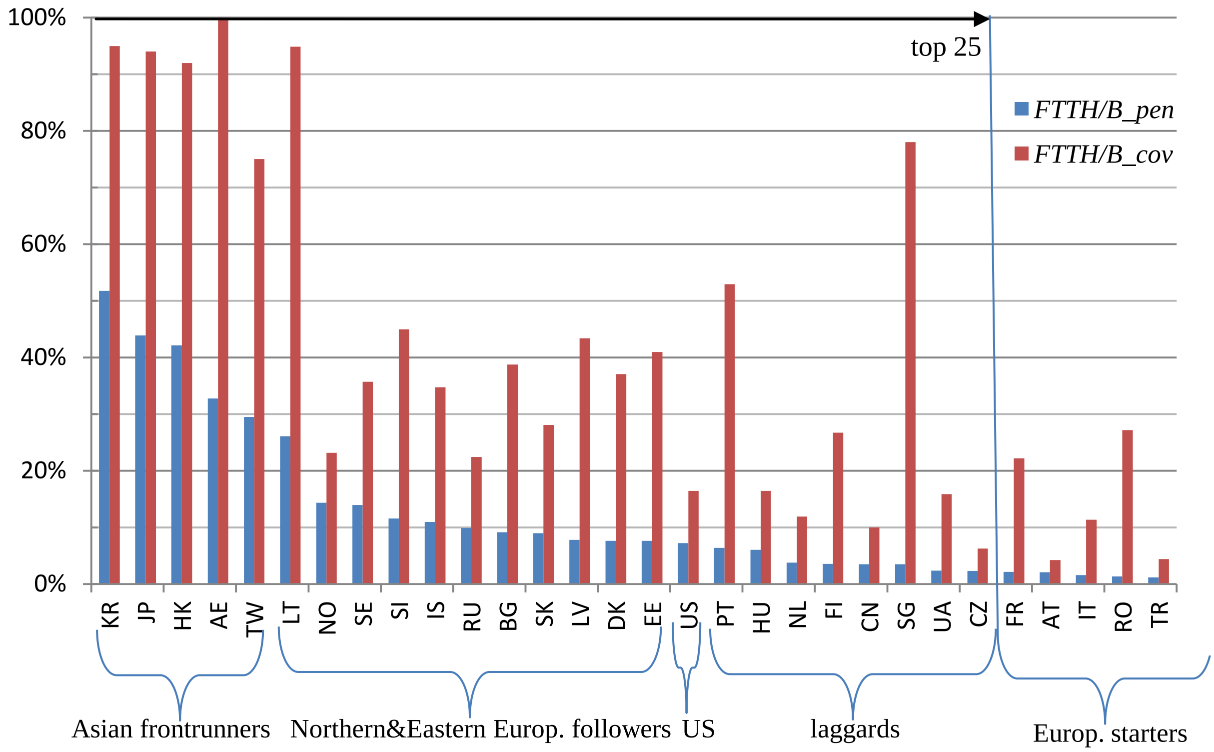
In section 3.1.2 we critically scrutinized the adequacy of cost-based regulation and the role of service-based competition against the background of NGA investment incentives. Figure 1 contains a global FTTH/B ranking of NGA deployment and penetration rates which includes all economies with a household penetration greater than 1% as of June 2011.[24] Thus, individual countries are ranked according to subscription rates but supplemented with their coverage levels.[25] As Figure 1 shows, the most mature fibre nations are KR, JP and HK (“Asian frontrunners”), with nearly full coverage (> 90%) and penetration levels between ~52% and ~42%. The leading Asian countries (including TW and AE) are followed by a couple of Northern and Eastern European economies (“European followers”) with coverage of 30% to 40% and penetration levels between ~26% (LT) and ~7.6% (EE).

[23] These regions clearly represent the global “NGA hotspots”, with 49.5 million FTTH/B subscribers in Asia, 10.2 million subscribers in Europe (including Russia) and 7.3 million subscribers in the US. The other regions represent less than 1 million FTTH/B subscribers (IDATE, 2011).

[24] The two-letter country codes (CC) in Figure 1 and below follow the ISO standard.

[25] There is a strong and positive correlation between coverage and penetration, with a correlation coefficient of $\rho = 0.87$ for the observation units in Figure 1 as of June 2011. Substantial and positive correlation appears to support our basic assumption that relevant policy actions tend to affect both, supply in terms of coverage as well as demand in terms of penetration.

Figure 1: Global FTTH/B ranking of penetration and coverage levels (June 2011)



Interestingly, within the group of the top 25 ranked economies no less than ten can be assigned to the cluster of "Eastern European followers". One can safely assume that the lack of well-established legacy infrastructure simplified migration towards new infrastructure considerably and seems to have opened up an opportunity to directly deploy investment-intensive ("high-end") FTTH/B networks at comparatively low cost. Eastern European followers not only benefit from the absence of a replacement effect right from the beginning, but are much less negatively affected by the regulatory induced wholesale and the ARPU eliminating effects (see section 3.1.2) at the same time.

The group of "Northern European followers" (NO, SE, IS, DK) shows – similarly to the broadband strategies in JP and KR – a long-lasting history of state aid programs which made the Scandinavian nations European forerunners in international comparison of broadband penetration (see Picot & Wernick, 2007, p. 667 and section 5.2). Moreover, in Northern Europe energy utilities and municipalities became the most important alternative operators, which now dominate the FTTH/B market in the Nordics and NL (Finnie, 2011, p. 7; OECD, 2011, p. 8).

Remarkably, out of the group of central, western and southern European countries only NL and PT are ranked within the top 25 FTTH/B economies but still below the US ("laggards"). The disproportionally high coverage rate in PT can be in parts attributed to ambitious funding programs of the Portuguese government (see section 5.2, Table 3). Furthermore, the regulatory regime in PT largely exempted the incumbent operator from active and passive wholesale remedies (Cullen International, 2010, Table 4). NL is unique in Europe, first with respect to the above-mentioned involvement of municipalities (and housing authorities) and, second, due to the long-established and nation-wide duopoly structure in the Dutch fixed broadband markets. However, most of the other EU states (”European starters”) show rather low subscription levels, at ~2.1% (FR) or even as low as 0.5% (including major economies such as DE, PL, EL or UK). Overall, the vast majority of European starters are still at the very beginning of NGA deployment and adoption. Especially incumbents play a secondary role in FTTH/B deployment in these countries so far.[26] Incumbency persistence against NGA deployment appears to be partly due to the negative impact of regulation on infrastructure investment, but also due to well-established copper legacy infrastructure in these countries. Regarding the latter, the replacement effect appears to be particularly intense for incumbents here, which gets reinforced in view of the above-mentioned progress on “second life” copper technologies.

The US is ranked just below the group of European followers (7.2%) but well above the average of EU27 countries (~2%, number not reported in Figure 1). With reference to NGA coverage levels, the difference between the developments in the US (~16.4%) and the EU27 (~11%) is similar. It is worth emphasizing that the US regulator (FCC) has fully reversed its comprehensive unbundling regime imposed on the access network in the first phase of liberalization. In 2003, FCC began to remove line-sharing obligations and to largely exempt fibre infrastructure from unbundling obligations (Triennial Review Order 2003, refined in 2004). The decision was based on dynamic efficiency considerations and on the conclusion that incumbents (owning legacy infrastructure) had no significant cost advantage in deploying new network infrastructure (ITU, 2009, p. 80). Verizon´s request for removal of any ex ante regulation for high-speed broadband infrastructure was adopted by the FCC in March 2006. Similar forbearance reliefs followed for other major US network operators in 2007 (OECD, 2011, p. 11).[27] Since the beginning of broadband/NGA deregulation the US has experienced remarkable growth in fibre investment and subscriptions (see Figure 2 (c)), with the largest fixed-line provider, Verizon, investing about $23 billion for its fibre-based network roll-out. Verizon has now by a very large margin the most FTTH subscribers in the US (~4.1 millions) and ranks among the top ten FTTx operators worldwide (IDATE, 2011).

Regulatory regimes in (leading) Asian economies are much more heterogeneous than within the EU. Some countries, such as JP, impose wholesale access obligations which are similar to the EU framework in extent and scope. The Japanese incumbent operator is subject to comprehensive unbundling obligations including line sharing (for DSL services) as well as unbundling fibre loops and interoffice fibre (ITU, 2009, p. 70). The Korean government mandated unbundling relatively late in

[26] According to the FTTH Council Europe, around two thirds of FTTH/B deployments in Europe (EU35) are due to activities of municipalities, utilities and alternative telecommunications operators, and only one third of FTTH/B deployment is linked to investment of European incumbent operators (Source: http://www.ftthcouncil.eu/documents/Reports/Market_Data_December_2011.pdf; Date: December 2011).

[27] The FTTx market in the US is basically dominated by two major operators: Whereas Verizon focused on FTTH deployment (21.5 million homes passed), AT&T opted for FTTC technology (29 million). Both compete with cable operators which have been offering services based on DOCSIS 3.0 (65 million) since 2008 (IDATE, 2011).

2002 with an initial hands-off approach in broadband markets. There are, however, no unbundling obligations imposed with respect to the NGA infrastructure. In other leading Asian countries (HK, TW) comparable wholesale access regimes are not implemented (ITU, 2009, p. 67, 78). Besides such differences in regulatory regimes, the governments of most leading Asian countries show a high degree of interventionism in terms of coordinating ICT development, in combination with massive financial support to stimulate supply of NGA infrastructure and demand for NGA services.

5.2 Global FTTH/B ranking and state aid

According to the economic rationales in section 3.2, we expect NGA deployment to be partially linked to public subsidies. Table 3 provides an overview of major public NGA state aid programs of leading FTTH/B nations with two-letter country codes in column 1. Column 2 contains volumes of national funding programs expressed in euros per capita as well as in billions of euros (in parentheses). The countries are listed according to the household penetration rates in Figure 1. Column 3 gives a brief description of the national funding programs and refers to main broadband targets which have to be realized within a pre-defined timeframe (column 4). Column 5 indicates whether the state aid program is (in parts) targeted to supply white areas. The focus is on the most prominent and far reaching funding policies in Asia, Europe and the US, which are explicitly dedicated to NGA deployment. Thus, state aid programs targeted at conventional broadband technologies as well as municipal and other non-national activities are excluded, as are a few high-ranked countries where either no major NGA public funding projects are known or data is not available (such as AE). However, Table 3 includes supranational funding activities of the EU as well as highly ambitious state-aid programs in AU and NZ in separate rows.

From Table 3 we infer that within the cluster of Asian frontrunners massive public subsidies are already determined and put in place (KR, JP, TW but also SG). Especially for KR and JP, these programs represent a systematic continuation of public initiatives for broadband deployment which were initiated decades ago. Public funding and encouraging industry collaboration have been regarded as complementary measures after market liberalization.[28] Through these funding initiatives the governments not only provided substantial subsidies for infrastructure deployment but also enacted effective stimuli on the demand side. HK is an exceptional case in this cluster, as it relies almost

[28] Korea´s world leading role in terms of broadband and NGA penetration rates is due to massive public initiatives of the government issued as early as in 1987 (Falch & Henten, 2010, p. 5). The “Korean Information Infrastructure Inititative” was established in 1994, followed by various other governmental programs in order to promote a nationwide ultra-speed broadband network. The “e-Japan strategy” was initiated in 2001 with the goals of becoming the most advanced ICT nation and with 30 million high-speed subscribers (>10Mb/s). The government extended this programme in 2003 (“e-Japan strategy II”) and provided additional resources by means of subsidies, tax incentives and zero-interest loans for broadband providers. Finally, the government launched the “ubiquitous-net Japan” strategy in 2004 and the “IT New Reform strategy” in 2006 with the goal to provide broadband services to every household by 2010 (Atkinson et al., 2008, appendix D).

entirely on infrastructure competition as the main driver for NGA deployment. Based on intermodal platform competition in conjunction with hardly any forms of ex ante regulations, as well as geographic and demographic cost advantages,[29] HK exhibits high coverage levels without any complementary state aid initiatives (FTTH Council Asia Pacific, 2009). In the US, in turn, state funding for NGA is deemed to be necessary despite its deregulatory approach towards NGA infrastructure.

When looking at the European states, Table 3 indicates that only a few governments have already launched substantial state aid programs in order to stimulate NGA deployment and that these countries (SL, EE, FI, PT) also belong to the top 25 in Figure 1. In turn, it is striking that within the clusters of European laggards and starters national governments have not yet determined any (BE, DK, FR, DE, GR, IE, IT, NL, SE, CH) or any substantial (AT, ES, NO, UK) public funding for NGA projects so far (Cullen International, 2011, Table 29). As opposed to European starters, AU and NZ are examples of non-European countries which are also still lagging far behind in terms of current FTTH/B coverage and penetration, but where national governments reacted with far-reaching and probably the most extensive public funding programs worldwide (in per capita terms).

Among the leading Northern and Eastern European followers, only FI, ES and SL have currently implemented moderate state aid programs. But, as mentioned in section 5.1, the other Northern European fibre nations (DK, SE, NO) show a long-lasting history of state aid programs, which made the Scandinavian nations also the European forerunners in terms of broadband funding.[30] Moreover, in the Nordic countries, energy utilities and municipalities became the most important alternative operators, whose financing activities are not captured in Table 3.

[29] With a very high population density of 6,349/km^{2,} HK ranks fourth just below SG (7,148/km^2). Source: http://en.wikipedia.org/wiki/List_of_sovereign_states_and_dependent_territories_by_population_density.

[30] For instance, the Norwegian “Hoykom” program lasted from 1998 to 2008 with total grants of €95.7 million. SE implemented a national broadband support program from 2001 to 2007 with state funds of ~€375 million (Cullen International, 2011, Table 29). Broadband development in DK is based on a plan issued by the Danish government in 2001 (“Vision 2015: 100 megabits for all”) which systematically supports the demand side through the promotion of ICT usage in the public sector, education and research programs (Berkman Center, 2010, p. 261-263).

Table 3: National funding programs for NGA deployment

CC	Vol.	Description of programme	Time	White	Source
KR	18.4 (1)	Government builds ultra-broadband convergence network in combination with private investments. Goals: 100 Mbit/s for 14 million users until 2012; starting in 2012, government builds Gbit/s networks in big cities; wireless should be upgraded to 100 Mbit/s	2009 to 2012	yes	Analysys Mason (2010); Doose et al. (2009, p. 30)
JP	13.7 (1.73)	Broadband network is fully funded by government, but entirely constructed by private company. Goals: FTTH/B high-speed broadband with 90% coverage in 2010	2009 to 2010	yes	Doose et al. (2009, p. 14-16); Berkman Center (2010)
TW	27.2 (0.63)	Direct investment in passive infrastructure. Goals: Deploying optical fiber pipelines and advancing ICT by promoting wireless broadband services	2003 –	no	Analysys Mason (2010)
US	8.5 (5)	Direct funding of individual projects to promote universal broadband access. Goals: Different NGA technologies; 100 Mbit/s for 100 million user and at least one Gbit/s connection to every municipality	2010 to 2020	yes	Analysys Mason (2010)
SG	261 (0.55)	Government establishes two vertically separated operating companies. Goals: To connect all homes and businesses with fiber by 2015, with some homes getting the 1Gbit/s access services by 2010	2009 to 2015	no	Analysys Mason (2010); Doose et al. (2009, p. 27-29)
SL	19.7 (0.04)	Public funds cover about 30% of the investment. The FTTH projects taken into consideration are "open broadband networks" Goals: To provide FTTH access in white spots	2008 –	yes	Analysys Mason (2010)
EE	47.7 (0.06)	Government plans to construct a nationwide high-speed broadband network. Goals: to provide 100Mbit/s coverage to 90% of the country by 2012, with the remainder of the population to be connected by 2015.	2009 to 2016	yes	Analysys Mason (2010)
FI	12.3 (0.07)	Public funds paid to the builders of active and passive infrastructure. Goals: Internet access for 100% at speeds of >1Mbit/s by end of 2010 and 100Mbit/s by 2015	2008 to 2015	yes	Analysys Mason (2010); Cullen International (2011)
PT	75 (0.8)	Government offers funding facilities while private operators are collaborating. Goals: 50% population coverage in each rural area within two years from when contract becomes effective	2009 to 2029	yes	Analysys Mason (2010); Cullen International (2011)
EU	2 (1)	Direct co-funding (Structural and Rural Development EU Funds) of individual projects subject to broadband/NGA state-aid guidelines and open tender procedures. Goals: Digital Agenda for Europe: 30 Mbit/s for 100% of households (coverage) and 100 Mbit/s for 50% (subscriptions)	2010 to 2020	yes	European Commission (2008, 2009)
AU	1202 (>15)	Government establishes new corporation, holds majority of shares during construction; corporation and incumbent are vertically separated; private co-investment is expected. Goals: Up to100 Mbit/s for 90-93% of FTTP (= fiber to homes, workplaces and schools) by 2018; wireless for remaining 7-10% with 12 Mbit/s	2010 to 2018	yes	Analysys Mason (2010); Given (2010, p. 4-8)
NZ	169 (>0.8)	Government establishes investment corporation; vertical separation of incumbent. Goals: Up to100 Mbit/s for 75% of population by 2018	2010 to 2018	yes	Analysys Mason (2010); Given (2010, p. 544)

When looking at Europe as a whole, the EC approved €1.8 billion in public funds for high-speed broadband development projects in EU member states in 2010.[31] These funds are especially targeted towards broadband deployment in rural and remote (white) areas. Generally, in most cases public funding is also targeted at closing supply gaps in white areas (column 5).[32] The amount approved by the EC in 2010 is more than four times the amount in 2009, which indicates that there is an awareness that a lot of catching up has to be done in EU member states. In addition, in its NGA recommendation the EC emphasizes the necessity to lower deployment costs by granting access to passive infrastructure elements, simpler access to rights of way and by allowing co-investment and co-ordination of civil works (European Commission, 2010a, recitals 12, 15, 19, 27, art. 13, 16).

5.3 Diffusion analysis

Based on the comparative analysis in sections 5.1 and 5.2, we now examine the different stages of NGA adoption for representative countries, with a sufficient number of observations and for “clusters” of countries which appear to be sufficiently homogenous.

5.3.1 Methodology

The vast majority of the related empirical literature finds that diffusion processes are best described through an S-shaped curve such as Gompertz, log reciprocal or logistic functional forms. The latter is most widely used for estimating S-shaped adoption processes of new communications technologies with aggregate data.[33] The logistic curve captures network effects which typically underlie all ICT diffusion processes: The value of a new technology increases with the subscriber base, as more and more content will be provided by operators and due to higher mutual accessibility of users. However, ultimately, growth will decline as the stock of subscribers converges to the total number of potential subscribers. In the case of fixed broadband communications, this number is limited by the number of households (*HH*) per country, whereas mobile subscription could eventually converge to the total population.[34]

Our empirical baseline specification draws on Grajek and Kretschmer (2009) and takes the following form with three interpretable parameters:

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[31] See the press release of the EC available at: http://europa.eu/rapid/pressReleasesAction.-do?reference=IP/11/54&format=HTML&aged=0&language=EN&guiLanguage=en.

[32] Exceptions (such as TW and SG) are due to country-specific demographic and topographic conditions.

[33] See inter alia e.g. Geroski (2000), Grajek and Kretschmer (2009), Czernich et al. (2011), Gruber and Verboven (2001) or Lee et al. (2011). According to Czernich et al. (2011), the logistic form captures appropriately the so-called ”extensive margin of diffusion“, i.e., penetration, which we are interested in, whereas it would fail to capture the “intensive margin of diffusion”, i.e. usage intensity.

[34] In mobile communications, saturation levels might even exceed the total population due to the co-existence of pre-paid and post-paid products and multiple SIM cards. In case of the non-mature and household related NGA deployment, it is, however, quite safe to assume that the fraction of adopters is bound between 0 and 1.

(1) $$FTTHB\_pen_{it} = \frac{FTTHB\_pen_{it}^{*}}{1+\exp(-\beta(t-\lambda))} + \varepsilon_{it}$$

$FTTHB\_pen_{it}$ denotes the actual number of subscribers ("homes connected"). $FTTHB\_pen_{it}^{*} = \gamma HH_{it}$ denotes the maximum number of adopters or the saturation level in country/cluster i at time t and therefore γ denotes the maximum share of households.[35] λ, the point of inflection, measures the timing of adoption as it shifts the logistic curve forward and backwards on the time line. Since the logistic curve is symmetric around the inflection point, λ represents the number of periods where half of the saturation level is reached. At the inflection point the diffusion curve takes its maximum value of the growth rate ($d^2(FTTHB\_pen_{it})/dt^2 = 0$). When differentiating equation (1) with respect to time, one can see that *ß* measures growth of adoption relative to its distance to the saturation level ("speed of diffusion"):[36]

(2) $$\frac{d\mathrm{FTTHB\_pen}_{it}}{dt}\frac{1}{\mathrm{FTTHB\_pen}_{it}} = \beta\frac{\mathrm{FTTHB\_pen}_{it}^{*} - \mathrm{FTTHB\_pen}_{it}}{\mathrm{FTTHB\_pen}_{it}^{*}}$$

Equation (1) is estimated by non-linear least squares where the error term, ε_{it}, is assumed to be i.i.d.

5.3.2 Main results

Figure 2 depicts actual and fitted values of the FTTH/B diffusion process for the selected countries and clusters. First of all, the non-linear nature becomes evident in Figure 2 (a) to (f), which is re-emphasized for clusters by adding linear regression lines. A linear specification does not capture the epidemic character of the diffusion process and would overestimate saturation especially where adoption started later. The sigmoid shaped relationship becomes most visible for the single country presentations for the US (c) and for LT (f) but also for JP&KR (a).[37]

Table 4 provides the estimates of the diffusion parameters, where a reference is made to Figure 2 in the heading which defines the cluster labels. The saturation parameter (γ) can be estimated consistently in case of a sufficiently materialized diffusion process, which basically holds for the leading Asian countries only, most notably for JP&KR. For the Asian clusters (Asian_1 and Asian_2) the estimated saturation level suggests a maximum household penetration of slightly above 50%. Obviously, this number is close to the corresponding penetration rates shown in Figure 1 and thus suggests that saturation levels had almost been reached in JP&KR in 2011. Since the NGA adoption process is still

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35 Note that $FTTHB\_pen_{it} \rightarrow FTTHB\_pen_{it}^{*}$ as $t \rightarrow \infty$.

36 Note that as $FTTHB\_pen_{it} \rightarrow FTTHB\_pen_{it}^{*}$ then growth rate $\frac{d\mathrm{FTTHB\_pen}_{it}}{dt}\frac{1}{\mathrm{FTTHB\_pen}_{it}} \rightarrow 0$.

37 Whereas the logistic diffusion curve underlying equation (1) assumes symmetry around the inflection point, the Gompertz function is asymmetric. Fitted values for the Gompertz function show a rather similar diffusion process in comparison to the logistic S-shaped curve. However, on average the Gompertz function systematically overestimates saturation levels (results are available upon request from the authors). Therefore, and in line with the cited literature, we are confident that the logistic diffusion curve is the most appropriate functional form for our estimation purposes.

in its early stage in the non-Asian countries, the saturation parameter cannot be estimated consistently, and therefore we had to use an exogenously fixed saturation level. For the Nordics and the US we decided to refer to the level of broadband penetration at the beginning phase of NGA deployment and adoption (see Czernich et al., 2011). According to the OECD broadband statistics, conventional broadband penetration per household in these countries was around 50% in 2006.[38] A similar argument is, however, not feasible for the Eastern European countries, where broadband penetration based on first generation copper and coax infrastructure was quite low in 2006 ("no legacy"). But, in view of one of the major broadband objectives of the Digital Agenda,[39] it seems to be meaningful to also apply the same saturation level to Eastern European countries (Figure 2 (e) to (f)). Moreover, since a maximum adoption rate of around 50% has been estimated for leading and highly broadband affine Asian countries, we are confident that this saturation level represents a realistic ceiling for the other (non-Asian) countries as well, at least for the foreseeable future.

The inflection point parameter (λ) is measured in periods elapsed since the first half year of 1960 (*date*). For instance, a date value of 100 stands for the first half year of 2010 (2010h1). The diffusion process started in date period 82 = 2001h1 and in date period 88 = 2004h1 in Figure 2 (a) to (c) and Figure 2 (d) to (f), respectively. If we impose a 50% saturation level ("sat") for the US and European countries, we can infer that the inflection point is reached much earlier in leading Asian countries (2007h2 (Asian_1) and 2008h1 (Asian_2)). Requiring a 50% saturation level shifts the inflection point many periods ahead in non-Asian countries. For instance, the inflection point and thus half (!) of the saturation level will be reached not before 2015 ($\lambda = 110.5$) and 2014 ($\lambda = 108.2/108.6$) in the US (US_sat) and Northern/Eastern European countries (Nordics_sat/Eastern_sat), respectively. In this view, the before-mentioned target of the Digital Agenda seems to be too ambitious for most European followers (~5 years), let alone for European laggards and starters.

[38] Source: http://www.oecd.org/document/7/0,3746,en_2649_34225_38446855_1_1_1_1,00.html.

[39] According to the European Commission (2010b, para 2.4) the EU "seeks to ensure that, by 2020 […] 50% or more of European households subscribe to internet connections above 100 Mbps".

Figure 2: FTTH/B penetration levels in selected countries and clusters

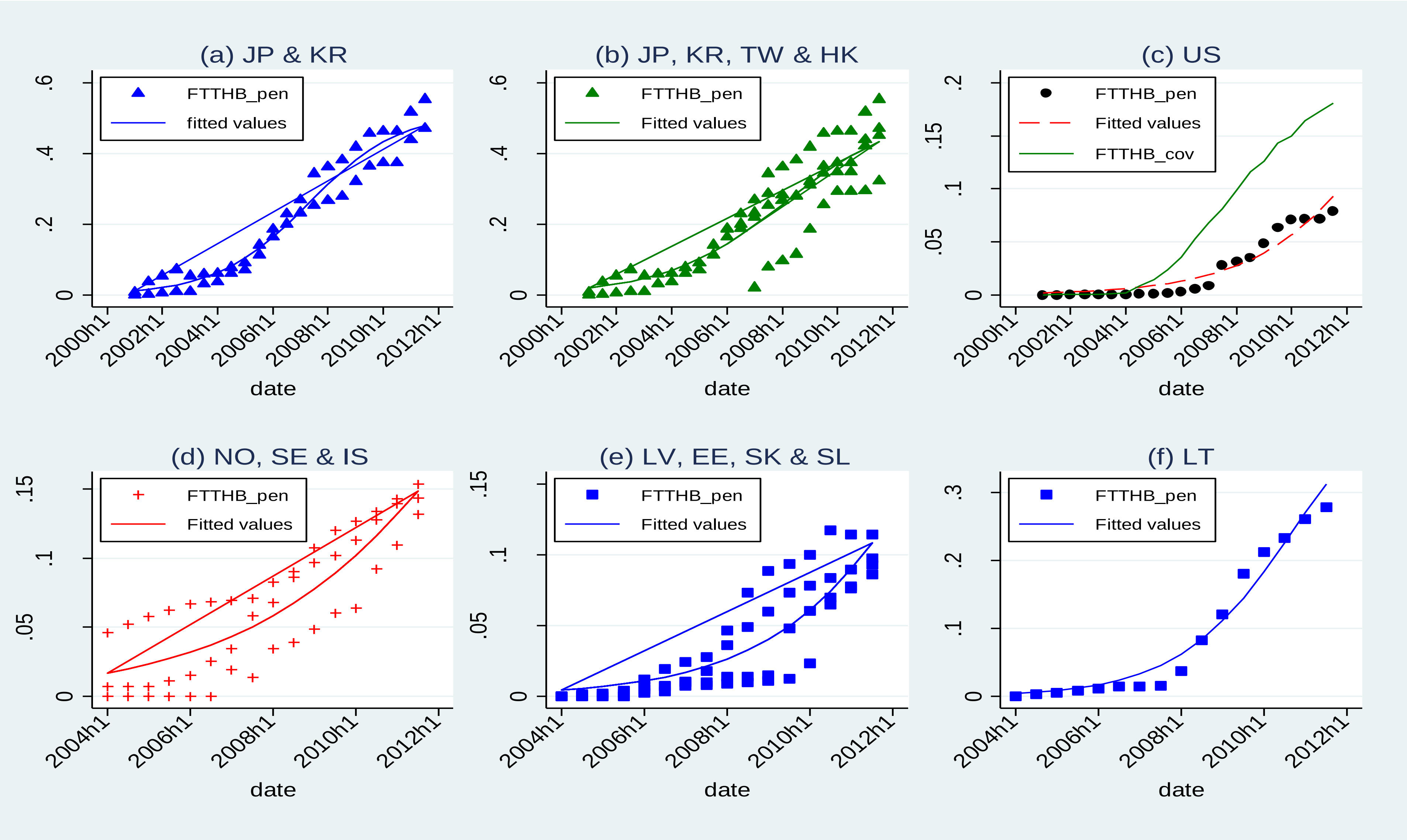

Table 4: Estimation results for diffusion equation (1)

Model nr.	(1)	(2)	(3)	(4)	(5)
Cluster label	**Asian_1**	**Asian_2**	**US_sat**	**Nordics_sat**	**Eastern_sat**
Cluster definition	Fig. 2 (a)	Fig. 2 (b)	Fig. 2 (c)	Fig. 2 (d)	Fig. 2 (e)
γ	0.517^{***}	0.523^{***}			
(saturation l.)	(16.99)	(5.99)			
ß	0.301^{***}	0.230^{***}	0.196^{***}	0.166^{***}	0.230***
(speed of diff.)	(9.23)	(4.61)	(9.91)	(9.54)	(9.92)
λ	94.58^{***}	96.20^{***}	110.5^{***}	108.2^{***}	108.6***
(inflection p.)	(163.78)	(54.02)	(104.09)	(111.35)	(131.46)
adj. R^2	0.982	0.935	0.949	0.910	0.871
F	786.0	316.9	207.6	244.5	217.4
RMSE	0.0370	0.0700	0.00844	0.0240	0.0182
N	44	66	22	48	64

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. t statistics in parentheses. The nonparametric "runs" test indicates positive serial correlation in the residuals. However, inclusion of heteroscedasticity and autocorrelation consistent variance estimators (Newey-West) leaves t-statistics virtually unchanged and highly significant. Shapiro-Wilk and Shapiro-Francia tests indicate that we cannot reject the null hypothesis that errors are normally distributed in models (1) and (3) as well as in case of LT (Figure 2 (f)). Cluster heterogeneity in the other models, however, induces non-normality and less efficient estimators. Saturation levels ("sat") are fixed at $\gamma = 0.5$ for models (3), (4) and (5).

The speed of diffusion ($ß$) is highest in leading Asian countries, with $ß \approx 0.3$ in JP&KR (Asian_1) followed by the extended cluster of leading Asian fiber nations (Asian_2) and Eastern European economies (Eastern_sat) with $ß \approx 0.23$.[40] Our analysis in sections 5.1 and 5.2 suggests that the success in the Asian clusters appears to be due to massive public government initiatives and demand and supply side country characteristics, whereas high growth rates in Eastern European economies appear to be primarily due to much lower consumer migration costs in conjunction with a hardly pre-existing replacement effect at the beginning of the diffusion process. In turn, growth rates for Northern European frontrunners ($ß \approx 0.17$) as well as for the US ($ß \approx 0.2$) are substantially lower. Needless to say, growth rates in other European countries (laggards and starters) are much lower and thus cannot even be estimated consistently.

6 Summary and conclusions

Most European countries are lagging far behind leading Asian fiber nations such as JP, KR, TW and HK, but also behind the development in the US in terms of both, coverage and penetration levels. According to our estimates, JP&KR are around 6.5 years ahead of European followers. However,

40 The speed of diffusion would be higher for Eastern_sat if we also included LT in model (5). However, LT is growing much faster than the other Eastern European countries, which would bring about additional cluster heterogeneity and significantly poorer fit statistics.

some Northern and Eastern European countries have experienced remarkable growth in NGA rates. Whereas the progress in NGA deployment and penetration in the Nordics is mainly due to comprehensive state aid broadband policies and a strong participation of municipalities and energy utilities, the Eastern European countries benefit from low migration costs towards NGA infrastructure and have experienced the highest growth in penetration rates in Europe.

Europe´s gap in NGA deployment was recognized by the EC and explicitly addressed in its Digital Agenda, which specifies ambitious goals in terms of coverage, penetration and bandwidth characteristics. However, in line with the literature cited in section 2, our analysis indicates that the strict cost-based mandatory access regime underlying the EU regulatory framework is at odds with these aims. International comparison shows that there are essentially three ways to achieve a fast and comprehensive NGA roll-out: (i) Market-based incentives, such us US-like deregulation strategies, have proved to effectively stimulate NGA investment and penetration. (ii) Direct state subsidies, as seen in many East Asian countries and, more recently, also in AU, NZ or SG, can be considered as relevant, especially to supply white areas. (iii) As the case of Eastern European fibre nations has shown, progress in infrastructure roll-out and adoption rates is often due to favourable country-specific supply and/or demand conditions. According to our results, in the absence of (iii), applying neither (i) or (ii), as the sector-specific EU regulatory framework appears to suggest, would not allow achieving the ambitious goals outlined in the Digital Agenda.

This result is of significant relevance for future policy decisions, as the setting of the regulatory design for emerging NGA infrastructure is still pending in many EU27 member states. In order to reduce negative investment incentives, ex ante regulation of NGA infrastructure should be directed to increase pricing flexibility (in the direction of full deregulation) and – in view of the long term nature of NGA investment – be binding and stable and defined as early as possible in order to help to reduce overall investment risk. Ideally, regulators switch from the asymmetric (legacy-based) regulatory paradigm to a more symmetric one where NGA regulation is primarily directed towards lowering total costs by means of an industry coordinating role and enabling cooperation models.

Finally, state subsidies might also be subject to governmental failure, namely whenever private investment is crowded-out (in non-white areas) or in case realized NGA coverage persistently exceeds penetration rates by a large margin, as it can be inferred from our empirical analysis for leading Asian countries. Briglauer and Holzleitner (2012) model the inefficiencies in the design of current NGA funding practice in the presence of asymmetric information. As a consequence, the higher the potential of governmental failure and the higher the adverse effects of sector-specific regulation on efficiency and welfare, the more the burden of proof is shifted in favor of a deregulatory approach.

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